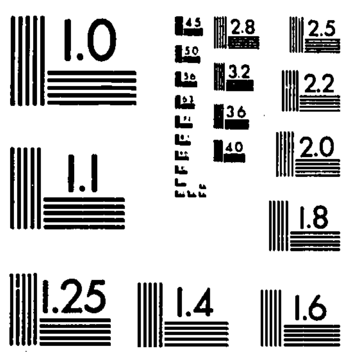

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ABSTRACT

This monograph provides a vision of the future for vocational educators in a position to improve programs, such as teachers and administrators of local educational agencies and state leaders who set priorities in educational agencies. The monograph addresses nationwide technological concerns of the computer, image storage and creation, and communications. It promotes understanding of organizational factors and the learning processes needed to make good use of the computer hardware and software tools becoming available for educational programs. The paper is organized to provide ideas on developing skilled workers, selecting useful hardware and software, and interpreting trends in educational technology. Examples of technological application in industry are cited, and likely future trends are indicated. The monograph provides change-oriented educators with insights into future use of technology and promotes an increased awareness of future trends, uses of technology in education, and priority research and development needs. A glossary of computer terminology is provided. (KC)

Information Series No. 268

EDUCATIONAL TECHNOLOGY IN VOC ED

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WICAT, Inc.

The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road
Columbus, Ohio 43210

1984

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FOREWORD

Educational Technology in Voc Ed presents an overview of the latest computer technologies and suggests applications for these innovations in vocational education. Some examples of innovative training programs are presented. Future developments and needed research are discussed.

This paper is one of nine papers produced by the National Center Clearinghouse's Information Analysis Program in 1984. It is hoped that the analysis of information on topics of interest to the field of vocational education will contribute to improved programming. Papers in the series should be of interest to all vocational and adult educators, including federal and state agency personnel, teacher educators, researchers, administrators, teachers, and support staff.

The profession is indebted to Dr. Joseph I. Lipson for the scholarship demonstrated in the preparation of this paper. Dr. Lipson is Group Director for WICAT Systems, Inc., in Orem, Utah. WICAT is an educational institute devoted to furthering the use of advanced educational technology and instructional design to improve the quality of education. Dr. Lipson was formerly Director, Division of Science Education Development, National Science Foundation.

Dr. Bernard Ferreri, Associate Vice Chancellor of the City College of Chicago; James Zigerell, Director of the Instructional Telecommunications Consortium, American Association of Community and Junior Colleges; and Marta Fisch and Dr. Norman Singer of the National Center for Research in Vocational Education contributed to the development of the paper through their reviews of the manuscript. Staff on the project included Dr. Wesley Budke, Dr. Judith Samuelson, and Catherine Thompson. Ruth Nunley typed the manuscript and Janet Ray served as word processor operator. Editorial assistance was provided by the staff of Editorial Services at the National Center.

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Executive Director
The National Center for Research
in Vocational Education

EXECUTIVE SUMMARY

This monograph provides a vision of the future for vocational educators in a position to improve programs. These are teachers and administrators of local education agencies and state leaders who set priorities in educational agencies. This monograph addresses nationwide technological concerns of the computer, image storage and creation, and communications. It promotes understanding of organizational factors and the learning process needed to make good use of the computer hardware and software tools becoming available for educational programs.

The paper is organized to provide ideas on developing skilled workers, selecting useful hardware and software, and interpreting trends in educational technology. Examples of technology application in industry are cited and likely future trends are indicated. This monograph provides change-oriented educators with insights into future use of technology. The reader will gain an increased awareness of future trends, uses of technology in education, and priority research and development needs.

Computer logic, combined with audiovisual and communications technologies, promises a new level of instructional technology for the future. However, early technologists overestimated the ability of their machines to promote learning and underestimated the (1) difficulty of writing good lessons for computer-based systems and (2) the importance of human interactions in learning. Two decades after the first attempts at computerized instruction, available and emerging educational technology is beginning to fulfill the hopes of the pioneers in this field.

Educational technology exhibits great potential for delivering effective education, but first computer-based instructional systems must be perfected. Research provides a great deal of information about environmental factors influencing the learning process. Based on this research, the following factors should be considered in the design of optimal, computer-based instructional systems.

- **Declarative versus Procedural Learning:** A computer-based instructional system that simulates procedural learning is likely to be superior to classroom instruction or a limited amount of on-the-job training.

- **Images and Logic:** Visual images projected by the computer can approximate the information contrained in the actual work environment. Students who perform simulated activities using the computer can pick up subtle cues that facilitate their learning of complex operation.

- **Computer Logic:** Trainees can interact with a computer-coordinated learning environment in a systematic manner. Likewise, a computer network, combined with telephone contact, reduces a student's isolation and enriches the quality of their learning experiences.

Economic pressure to reduce the cost of educational services provides an incentive for the use of computerized instruction. Computer hardware is being redesigned for increased memory, improved audio capability, and extended availability and use. Computer software is becoming more user friendly and more widely available. The following factors have potential for influencing vocational education programs:

- Increased computational power and memory
- Voice synthesis
- Voice recognition
- Fiber optics and satellite communications
- Large, flat, high-resolution color screens
- Portable microcomputers of very small size
- Artificial intelligence
- Human/computer symbiosis
- Implant technology
- Embedded training

The following recommendations are suggested to help vocational education capitalize on the new computer-based information technologies:

- Organizations must devote more effort to designing organizational structures that will help workers be more productive and make use of the latest technology.
- Education and training systems must apply cognitive science to education, training, and retraining.
- We should develop a national commitment to excellence in training.
- Industry must organize and fund industrywide course development projects.
- Research on the learning process in vocational education should be expanded.
- Support is needed for research and development in the training applications of the new information technologies.
- The educational system should develop professional undergraduate, graduate, and post-graduate degree programs for people who will create instructional materials for the new computer-based education technology.

INTRODUCTION

This monograph provides a vision of the future for vocational educators in a position to improve programs. These are teachers and administrators of local education agencies and state leaders who set priorities in educational agencies. This monograph addresses nationwide technological concerns of the computer, image storage and creation, and communications. It promotes understanding of organizational factors and the learning process needed to make good use of the computer hardware and software tools becoming available for educational programs.

The paper is organized to provide ideas on developing skilled workers, selecting useful hardware and software, and interpreting trends in educational technology. Examples of technology application in industry are cited and likely future trends are indicated. This monograph provides the change-oriented educator with insights into future use of technology. The reader will gain an increased awareness of future trends, uses of technology in education, and priority research and development needs.

Skilled Workers as Resources

Workers today are faced with requirements for increased knowledge and skill in dramatically new areas. According to Peter Drucker (1983), this reverses a trend of several decades in which productivity was increasing without the need for increased knowledge and skill on the part of the average worker. Now the combination of foreign competition and automation is altering the job landscape.

A report by the Office of Technology Assessment (1982) predicts that the next decade will see a remarkable rise in the use of high technology—computers and communications networks—for vocational education. This forecast may well prove accurate in spite of the following barriers to innovation:

- A natural tendency of organizations to resist change (Lipson 1981)
- Government policy that inhibits the development of education technology
- Business policies designed to maxmimize short-term profits at the expense of the long-term profit that could result from improved vocational education
- A shortage of the talent needed to realize the potential of high technology in training

The forces that will help to overcome these barriers include the following:

- Rapid changes in job requirements as the result of new technology are causing training costs to escalate.

- Some jobs are becoming so complex and dangerous that the capacity of some traditional systems to meet training needs is proving inadequate (e.g., operating and maintaining a nuclear plant, maintaining complex equipment in the field).

- As technology continues to make whole classes of jobs obsolete, social and political pressure will mount to set up retraining programs to fulfill needs not being met by conventional means.

- Interactive, computer-based education is becoming increasingly attractive and cost-effective as computer, optical-image storage, and communications technology make rapid improvements.

- Understanding of the learning process is reaching the point where we can design effective learning environments based on the latest technologies. These designs will combine human teachers and computer-based systems to provide dialogue, access to vast amounts of information, expert models, and advanced computer programs.

Levin and Rumberger (1983) assert that most new jobs in the coming years will be on the low-skills end of the job spectrum. It may be argued that this outcome is not inevitable. New technology markedly increases productivity, creating new opportunities. The word processor significantly reduces the labor-intensive work of the secretary, for example.

Foreign competition will not let us easily ignore the productivity gains promised by technology. Human talent and time will be released by this revolution in productivity in almost every field.

Technology-induced productivity has released time, by and large, for increased schooling and more creative and challenging jobs. Today, medicine, education, and research and development take a large fraction of our gross national product. This is possible because only a small percentage of our population is required to feed, house, and clothe the rest of us. Thus, technology leads to a better educated worker who becomes a new resource. Vocational education has an important role to play in transforming workers in the new high-tech society. This better-educated worker is lost if some of the profits of increased productivity are not diverted to support a challenging and demanding vocational education system.

This argument suggests that a program of retraining aimed at increasing the skill levels of our work force is in the best interests of our citizens and society (Nussbaum 1983). This challenge can only be met through the appropriate use of the new technologies as intellectual tools (Molnar 1982). Advances in hardware development and software programs are needed to upgrade worker proficiency.

The rapid development of computer technology has paved the way for educational development. Computers touch the life of nearly every person in society. Each needs to learn about this technology to cope with needs in school, at work, and in the home.

The Status of Educational Technology

Articles (Metzcus 1983), books (Evans 1979; Patterson 1983; Texas Instruments 1978a and 1978b), dictionaries of computer terms (Chandor 1981) and television programs ("The Computer Program")* are available to introduce the neophyte to computers and computer terminology. Also

*"The Computer Program" is the title of a BBC television series.

available are computer programs (software) to teach the beginner about computers. Although even the simplest computer is so complex that it is almost impossible to understand everything about it, one can easily gain an appreciation of such concepts as input, computation, output, and data files. (See Glossary for definitions.)

Basically a computer is able (1) to carry out logical and arithmetical operations and (2) to store information in memory. From the simple combinations of logical operations and arithmetical computations, programs can be written that can carry out all the many computer operations ranging from serving as a bank teller to playing chess. A computer can execute millions of operations per second. In spite of their amazing capabilities, computers are not intelligent in conventional human terms. Evans (1979) states that present-day computers are about as intelligent as an insect, but reminds us that we should not feel too superior. The present level of computer capability has been achieved in a few short years—since 1950.

The present era of rapid development and application of computers began with the development of the solid-state transistor in 1947. The transistor replaced the vacuum tube, which was so large that computers were quite unwieldy. The integrated circuit improved on the transistor when it was discovered that a great many transistor elements could be etched into a tiny, thin square of silicon. The silicon "chip" led to the development of the microprocessor, and the microcomputer came into being in the midseventies.

From the earliest days of solid-state technology, instructional systems were designed for use on the computer. Computer logic, combined with audiovisual and communications technologies, promised a new level of instructional technology. The early technologists overestimated the ability of their machines, however, and underestimated the difficulty of writing good lessons for computer-based systems and the importance of human interaction in learning. In spite of these drawbacks, now about two decades after the first attempts at computer-based instruction, the available and emerging educational technology is fulfilling the hopes of the pioneers. Although educational technology is not synonymous with computers, it appears that microcomputers will dominate developments and will influence and integrate all other audiovisual devices.

Hardware

By the standards of a decade ago, the 8-bit, 64K RAM personal microcomputer* is an impressive device. Combined with peripheral devices such as floppy magnetic disks for information storage, joy sticks for manipulating the cursor, and voice synthesis programs, some very good interactive instructional software (some employing graphics) has been developed. However, experience with more powerful computers suggests that the computational power and memory of today's personal computers are inadequate for serious vocational education of the kind now needed.

At the other extreme from the small personal computer is the use of time-shared large computers (mainframes) as exemplified by the PLATO computer-based system. Sophisticated lessons have been written and used extensively for vocational education on such systems. The primary limitations of these systems are—

- the cost of telephone communications with the host computer,

*Eight bits refers to the amount of information that can be handled in a single operation; RAM stands for random access memory. (A full glossary of technical computer-related terminology appears at the end of this publication.)

- dependence on the maintenance schedule of the home computer, and
- the slow response time when information is transmitted over telephone lines.

In between the small personal computer and the large (mainframe) computer is the new generation of 16-bit microcomputers (Lu 1983). These can be outfitted with large capacity storage, large random access memory, and almost any peripheral device (e.g., voice synthesizers, videodisc players, voice recognizers, graphics plotters, touch sensitive screens). Priced in the range of ten thousand to twenty thousand dollars, these microcomputers are serving significant vocational educational purposes.

With some degradation of performance, several workstations can be connected to a single 16-bit microcomputer. The resulting price per student workstation then becomes about three thousand to six thousand dollars, depending upon the quality of the terminals used.

A key peripheral device is the videodisc under microcomputer control. Present industrial-quality videodisc players add about four thousand dollars to the cost of each student workstation. A videodisc stores a large number of the high-quality TV pictures that are critical to many training programs (e.g., medical diagnosis, equipment repair) requiring high-resolution images of photographic quality.

Student workstations with high-resolution color screens are presently too expensive for general use. However, moderate-resolution, single-color screens are available. As is to be expected, each time a peripheral device is added, the cost of a student workstation goes up. But the benefit of effective training is so great that even relatively expensive workstations (ten thousand to fifteen thousand dollars) can be justified on the basis of the increased productivity that could result from increased employee capability.

Software

Software tends to be limited by the computational power of the computer as well as the availability and talent of programmers. At the present time, the trend in educational computing is the development of high-level languages (e.g., TUTOR, a language used with the PLATO system) to aid the author who is not a proficient programmer in computer languages such as BASIC, PASCAL, or FORTRAN. High-level languages require a great deal of programming at lower levels. Thus, as the authoring systems and languages become more complex in order to be more convenient or "user friendly," increasingly large memories are required of microcomputers.

The most successful, educational software programs are those that provide the user with intellectual assistance in such tasks as word processing and planning. Examples of this type of program are authoring and course management programs. One such program is the WISE authoring system developed by WICAT, Inc. This system is menu driven, and it provides tools for managing logic and producing text and graphics. It requires large RAM capacity for central computer operation and a large information storage capacity for the lessons that are produced.

With some exceptions, most of the lessons developed for typical microcomputers are of low quality (Braun 1983). Most of the problem may be attributed to the inherent limitations of the small (8-bit) microcomputer with limited memory (RAM). When large amounts of computational power and memory are available, significant, practical, cost-effective lessons can be produced. Some are already being developed by such firms as Control Data, McDonnell Douglas, General Electric, IBM, and American Bell. However, today's most powerful computers are not very "intelligent"—i.e.,

not able to be an "interesting" conversationalist or tutor for the student. Improvements are steadily being made in this regard, however (Evans 1979).

Some very effective programs are available. Many additional programs are undergoing development. Several examples of computer-based vocational training programs follow.

Descriptions of Equipment Maintenance Training

The U.S. Army uses a ground-launched missile (the I-Hawk) that is controlled by a complex, computer-based electronic system. The control electronics are transported in the field by trucks. Because of the rough terrain, a large amount of field maintenance is required, and it must be performed by the average soldier. The standard method of instruction uses classroom lectures and tests. It would be almost impossible to simulate, on actual equipment, all of the things that can go wrong.

To explore the potential of computer-based simulations for providing training in troubleshooting maintenance, the U.S. Army commissioned the development of a computer-controlled, interactive videodisc. The I-Hawk training videodisc simulates hundreds of potential maintenance problems. Trainees receive the same kind of information as maintenance workers on the job. When a visual clue to the problem is needed, the student sees the picture by means of a television display from the videodisc. Here the still-frame capability of the videodisc* is critical since most of the time a single picture is needed.

When prepared for testing, the trainee can request any standard test. If a voltmeter is used, the display shows the face of the voltmeter. If an oscilliscope display is needed, a picture of that is shown. The student can view any suspect part and simulate replacement by a command to the computer. The computer keeps track of the complex logic of the simulation, and the videodisc displays the needed graphics. The student can keep trying possible solutions to a problem until a repair is made. The computer keeps track of the student decisions and keeps a score for the use of both the student and the instructor.

An evaluation of the effectiveness of computer/videodisc simulations reports impressive results (Gibbons 1983). The lowest final test score of students trained with videodisc simulation was about the same as the highest score of those using traditional training methods.

Training Customer Service Representatives

American Express was recently faced with the need to train quickly about three hundred employees for a new customer service facility in Salt Lake City. The cost for employee salaries, travel, instructor expenses, equipment, and space would have been very high if conventional classroom instruction were used. Such a large number of the employees were newly hired that they could not be trained on-the-job by experienced employees. The solution to the problem was to acquire thirty terminals connected to a single, powerful 16-bit microcomputer system capable of supplying lessons to all thirty terminals simultaneously.**

*Readers not yet familiar with the capabilities of the videodisc and the laser audiodisc are encouraged to obtain a demonstration from a video electronics distributor. Sony and Pioneer are the principle firms in the optical memory field at the present time.

**Whereas the system can provide instruction for thirty students, thirty instructors cannot write lessons at once. Writing lessons (authoring) places a much greater load on the computer than does student activity. Only about six authors can use the system simultaneously.

To produce the lessons, American Express sent three of their training personnel to WICAT's home office for three weeks. In that period of time the trainers learned enough about the WISE authoring system to begin writing lessons independently. WICAT provided continued support for both hardware and the lesson writers.

After the new customer service representatives were trained, the training facility was used for other training needs. Using the previously established method, large numbers of employees can be trained for a new operation in a timely and cost-effective manner.

Equipment Installation and Maintenance Training

Another impressive training program is that of AT&T, which allocated between $1 and $2 billion a year to training before the divestiture. (A large portion of this amount went to salaries paid to employees during training.) The court-ordered change in the corporate structure of the telephone and communication industry and rapid introduction of new high-technology equipment created a business environment involving competition and dynamic change.

Thousands of employees needed training to understand, install, and maintain new systems. Computer-based education appeared to possess the potential for controlling costs while providing effective training. The system selected included an authoring system, a 16-bit microcomputer system with touch sensitive screens, and an interactive videodisc. Each workstation was linked into the telephone network for the purpose of providing instructional management and student assistance. The system was, therefore, highly interactive and provided a wide range of options to students.

A demonstration lesson was developed. Several unique features, including the option to select instruction at three qualitatively different levels characterized this lesson. As a result of the demonstration, AT&T commissioned the development of a course using the system. AT&T trainers produced courses using the authoring system.

These examples of effective private-sector use of training via high technology are sufficiently impressive to justify the prediction that computer-based education can make a major contribution to the accelerating need for job skills training. However, one of the important limitations to effective use of technology is our understanding of the learning process. The way that we can apply our growing understanding of human thought processes is the subject of the next section.

THE POTENTIAL OF EDUCATION TECHNOLOGY FOR DELIVERING EFFECTIVE EDUCATION

Research has provided a great deal of information about the learning process and the factors in the environment that influence learning. Following are examples of learning theory that should be applied in the design of computer-based instructional systems.

Declarative Versus Procedural Learning

Much vocationally related learning involves learning specific trades, crafts, skills, or procedures. Most academic classroom instruction involves learning the facts of a subject. Whereas learning to recite the steps in driving a car or diagnosing a fault in an engine has value, abundant evidence exists that these procedures must be supplemented by "hands-on" instruction.

Researchers suggest that we begin to learn a procedural skill by first applying general rules to declarative knowledge of the procedure (Anderson 1978). As we become involved and experienced, we acquire both verbal and nonverbal (psychomotor) knowledge of the steps and options of a new skill. In a sense, we build a model of the skill in our heads. We can do many things that we cannot describe in words. How, for example, does a center fielder know how to run to the point that a batted ball will land?

This theory is supported by studies of the brain. It appears that psychomotor knowledge of procedures is stored in the brain separately from declarative knowledge. This implies that a system that provides intensive opportunities to simulate procedures (without danger to persons or equipment) is likely to be a learning strategy that is superior to either classroom instruction or a limited amount of on-the-job training with actual equipment. Sophisticated computer simulations, especially when combined with visual support from a videodisc, allow more trials, more systematic development, and more exploration of the consequences of various options than either on-the-job training or training using actual equipment. The simulations apparently build a complex model of the operation in the minds of the students so that when they actually come in contact with equipment, only fine-tuning of the procedural model is required to master the skill. This approach was used successfully to train the first astronauts, a skilled performance on their maiden voyage being critical.

Images and Logic

For most vocational education, visual images are needed to approximate, in simulations and other forms of instruction, the information contained in the actual work environment. The student must, for example, see how a tool looks when it needs to be replaced, see the skin color that results from a patient's illness, or see the changes that take place in a product as it goes through the steps in manufacturing.

Students who have the opportunity to observe an expert carrying out an operation apparently pick up many subtle cues that facilitate their learning of complex operations. Simulations of such procedures require photographically realistic images. Optical videodisc technology provides images of acceptable quality at a relatively low cost. Optical (laser) videodiscs provide single frames of realistic pictures for about one-tenth of a cent per picture (not counting the cost of equipment). This means that concepts requiring pictures (e.g., parts of a machine) and procedures can now be economically taught, whereas they previously could not.

The Need for Computer Logic

Visual images alone are not enough to provide adequate training. Trainees need to interact with their environment and to have this interaction logically coordinated. The trainee's level of prerequisite knowledge and skill must be evaluated with subsequent instruction assigned on the basis of that evaluation. Each response must be interpreted in order for the student to be given useful feedback and for the subsequent instructional activity to be determined. The requirement for the computer to interpret and respond to student responses and to assist the student in deciding what to do next is the greatest challenge to computer-based education. In some situations (e.g., simulations), no human can equal the computer. In other situations (e.g., interpreting a student statement), no computer can rival an expert human instructor. Clearly, at present, the optimal system provides the logic of the computer, the images provided by the videodisc, and a human tutor.

The importance of computer networks is quite obvious; people who have the expertise a student needs or who share a work problem are not available locally. In such cases, the trainee feels isolated, learning is more difficult, and motivation may lapse. A computer network, combined with telephone contact, reduces isolation and enriches the quality of learning. Electronic mail and electronic bulletin boards can update courses and can teach some things that are not included in courses (e.g., about a new product that is a major improvement for a particular task).

FUTURE TRENDS IN EDUCATIONAL TECHNOLOGY

Economic pressure to reduce the cost of standard devices, training, the economic incentive provided by the market for new devices, and the imagination of designers are all contributing to the move toward refined computer equipment, methods, and new products. In addition, more people than ever before are working on research and development throughout the world. The result is that, in the last few years, new developments have begun to arrive faster than predicted in many areas of technology. The implication for vocational educators interested in high technology is that it is necessary to have some source* for keeping up-to-date within the time that can be allotted to that task.

In the following sections, the discussion begins with near-term projections (five to ten years) and then moves to more speculative, long-range predictions (ten to fifty years).

Emerging Technologies

Even if the rate of increase in microcomputer computational power and memory (per dollar) slows, the effects of increases over the next ten years should be easily observable (Pournelle 1983). The consequence is that vocational educators will increasingly be released from the constraints of limited power and memory in microcomputers. This means that, almost automatically, students will have access to increasingly larger work-related information libraries at their workstations. Glossaries, picture libraries, job aids, expert assistance with diagnostic and troubleshooting problems—all these and more will be on-line.

Until recently, the cost of a given amount of computational power and memory was reduced by half every two years. Even if this rate slows to reducing by half every three years, ten years from now computers will be more than eight times as powerful and have eight times more random access memory than today's computers for the same price.

A second effect of increased power will be the continued development of high-level systems that will be much better at (1) interpreting almost anything a student says or does (natural language understanding) and (2) providing aids to authors. Lessons authored five to ten years from now will be both more user friendly and more interesting as more powerful computers become available.

In the long run, increased power and memory will arise from some breakthrough that we presently do not anticipate, but which most analysts confidently predict! Research points toward memory made of biological material that can reproduce itself and three-dimensional memory that can store millions of times more information than the memory presently available. But the breakthrough may come from some new concept of discovery. In 1945, no one could have predicted the discovery of the transistor and its impact on the future of computation—and society.

*One excellent source is the monthly publication, *High Technology*, P.O. Box 2808, Boulder, CO 80321.

The next section considers three ways of storing information that will compete with present methods during the next five to ten years—bubble memories, digital videodiscs, and audiodiscs. Each has significant potential when applied to vocational education.

Bubble Memory

A promising development for information storage is bubble memory. In this technology, magnetic bubble memory stores information in the form of cylindrical domains in a thin film of magnetic material (*Solutions* 1983). The domains are called "bubbles" because they look like bubbles under a microscope. Unlike the magnetic domains on audiotape or videotape, the bubble domains can be generated and detected with no moving parts.

At the present time, bubble memory is very expensive as compared with floppy and hard disks. However, bubble memory offers two great advantages:

- Bubble memory is nonvolatile. Unlike most random access memory capabilities, bubble memory is not erased by power failures.
- Bubble memory has no mechanical, moving parts, so from a maintenance point of view it is far superior to floppy and hard disks.

The slightest damage, wear, or misalignment can cause the disk drives used for floppy or hard disks to malfunction. Maintenance costs for disk drives are, therefore, very high. In addition, when a disk drive malfunctions, vital information can be lost. Also, the electrical energy needs of disk drives are so great that prolonged portable operation is not practical.

Bubble memory solves these problems and makes the powerful, notebook-size portable microcomputer practical. As improved manufacturing technology and competition result in more affordable bubble memory, computer-based vocational education will be increasingly effective. Its importance to vocational education is that it will permit a worker to carry a rugged, low-cost device to the work site or it will permit the computer to be incorporated into the equipment being used by the worker. In the longer run, a new version of bubble memory called bubble-wall memory may prove to be both practical and to increase present bubble memories by a factor of 100 ("Bubble Wall Memory" 1983). Instead of storing data (information) as the presence or absence of a bubble, the bubble-wall memory records data on the walls of individual bubbles.

Digital Videodisc

Videodiscs being used at present are primarily analog discs. Most of the computers in use require digital information. A watch with hour, minute, and second hands is an analog watch. A watch that displays the time in numbers is a digital watch. The traditional LP record is an analog recording. As the needle moves along the shape of the groove, the movement is converted into an electrical signal that is proportional to the movement of the needle. A digital recording would have the signal (pitch and loudness) electronically recorded as a series of numbers that are "read" and converted into a signal transmitted to the loudspeaker. In general, digital storage is more accurate, more efficient, and less subject to degradation over time.

A digital videodisc can store up to 200 million words (a billion megabytes) on its two sides. This is a much larger capacity than that of its forerunner, the analog disk. At one time, it was esti-

mated that a single digital videodisc could store all of the educational computer programs ever written. Depending upon the exact material and technique, some videodiscs can only be "read," that is the information is encoded at a factory and then the user can feed the information from the disc to a computer or other electronics. A different technique allows the user to "write once and then read", that is the user can encode the information wanted only once. Thereafter, no changes can be made. The most flexibility is achieved with very expensive systems that allow one to both record, change, and read digital information.

Digital videodiscs are not in widespread use today, but they are a serious contender for storage of large amounts of information at low cost.

Other efficiencies result when information is encoded digitally:

- The information is almost totally immune to degradation with time.
- The information can be used to transform the result efficiently. When a letter is digitally encoded, a small program permits selection of the letter size and font without taking up much information space.
- Computer programs can be stored directly on the videodisc.

Digital videodiscs are presently much too expensive for use in vocational education. Their future potential importance lies in their immense capacity at low cost. When affordable videodiscs become available, they will make computer-based vocational education much more economical and effective.

Audiodiscs and Still-Frame Audio

In order to have sound along with a videodisc image, the disk must be operated at TV speed (thirty frames per second). This means that videodiscs cannot be used in the mode of a slide-tape program. In fact, in order to hear one-half hour of speech, all fifty thousand frames on one side of a videodisc must be used—fifty thousand pictures to get three thousand words.

Very often an instructor needs to talk for a considerable period of time to explain a single picture. Also, while a student is working with a piece of equipment and using pictures and speech for guidance (e.g., assembly or disassembly of equipment), extra time is required. Still-frame audio provides the means to do this. Each frame of a disk can hold either a single picture or about ten seconds of speech. Thus, one side of a twelve-inch disk can hold over one hundred hours of speech or fifty thousand pictures or some combination of these. Still-frame audio means that video and audio operate independently; while a single picture remains on the screen, the system can go on to play the audio tracks.

The importance to vocational education of this development is obvious. Many vocational training tasks require students to concentrate on a picture or diagram for some time. When instructions appear on the screen, they must redirect their focus from the diagram to the words and back again many times. Still-frame audio solves this problem. In addition, there is some evidence that students prefer not to work in silence after having been involved with an audio videodisc segment. Still-frame audio will, therefore, have instructional and, possibly, incidental psychological advantages.

Voice Synthesis

Low-cost voice synthesis has been available for some time (as the "Speak and Spell" toys demonstrate). In vocational education, great benefits can be realized from technology that permits the use of large amounts of computer-generated speech that does not have to be stored in fixed form—on audiotape, a sound disk, or a record. To change a recorded message using these technologies, a new recording must be made. In addition, a great deal of time is necessary to locate a particular message.

In contrast, computer-generated speech is almost always instantaneously available, and changes in the spoken message can be made quickly by a change in the computer program. Voice synthesis is an indispensable aid for computer-based instruction in tasks that require an employee to speak in a foreign language, for example. As early as the sixties, computer-based language instruction was shown to be clearly superior to traditional classroom instruction. The addition of powerful voice synthesis will make computer-based language instruction the method of choice. The technology is available and soon will be affordable for training.

Voice Recognition

It would be of great value for students to be able to give oral commands and responses to computers. Manual input devices tie students to the devices. For example, suppose a student has both hands occupied when information is needed from the computer. If a keyboard is being used, the student must stop the other activity to interact with the computer. Imagine the convenience of being able to say, "next frame," "show diagram," or "temperature 120," and have the computer execute the command or record the temperature. Also, many students who are not skilled typists are intimidated by keyboards and have difficulty using them to interact with computers.

A computer device that recognizes about two hundred selected words spoken by a given individual is available. The computer is "trained" (programmed) to recognize the voice of a particular student. The student repeats some key words several times and the computer voice-recognition program tunes itself to the sound. To program the machine, the student must speak clearly and distinctly.

Recognition of natural speech with its slurring and accents is a problem for computers. The solution to this problem is difficult because computer understanding of natural speech requires more than electronics. It requires the ability to recognize words through the use of context cues. Natural speech recognition by computers will improve with advances in artificial intelligence (AI—see section to follow).

The combination of voice synthesis, still-frame audio, and voice recognition technology will have a dramatic effect on the quality and motivational properties of computer-based training, releasing students from the keyboard and creating interest by providing them with a powerful world to control and from which to learn.

Fiber Optics and Satellite Communications

It was noted previously that computer networks aid instruction by providing access to information not locally available. Low-cost communications networks will be valuable for managing scattered training sites, sending out new course programs, and embedding trainees in a social network

that can provide guidance and assistance by allowing them to assist one another. The principle barriers to such systems are cost and the tendency for low-quality messages (electronic "junk mail") to compete for attention with important and desirable messages.

Both fiber optics and satellite communications technologies have the potential to provide digital communications at low cost. Fiber optics uses extremely thin, incredibly pure strands of glass to carry laser beams that transmit information. Satellite communications transmit information by having a ground transmitter send an electromagnetic signal (e.g., a television picture) up to a satellite, and the satellite then amplifies the signal and retransmits it down to a receiver. It is not yet clear which one will forge to the forefront or whether each will find its own niche. It is hoped that regulatory bodies will arrange for both to be available at low cost for educational purposes.

Large, Flat High-Resolution Color Screens

In understanding technical material, trainees often must relate text, diagrams, and equations. Limited screen size creates a need to reference information on another screen. This is like looking back and forth at different pages of a book that refer to each other. Windowing—the ability to call up on a computer screen portions of different frames at the same time—helps, but does not solve the problem because of the limited size of presently affordable computer screens.*

The best solution to the problem is to have large, flat, inexpensive high-resolution color screens that can handle four or five standard screens of information at one time. Alternatively, one can adjust the size of characters and graphics for best viewing. If only one screen is needed, the size of characters and graphics can be enlarged for better viewing. After decades of promise, flat screens are beginning to appear in portable television sets, cars, and computers. In 1984, for the first time, consumer products will replace military equipment as the main users for flat display panels.

These screens will be based on liquid crystal display (LCD) units, electroluminescent panels, or some newly developed technology. But they are now a reality. It will take a number of years for the price and quality of flat screens to match that of cathode ray tube (CRT) screens, but from now on the progress is sure to be steady.

Notebook Size and Attache-Case-Size Microcomputers

An additional advantage of flat screens is their small size. For example, flat panel of twelve inches by seventeen inches can be mounted in the top of an attache case and the keyboard and computer mounted in the bottom. With this technology, an individual will be able to carry almost anywhere a computer with a screen that can display two pages of information.

As computer memory becomes less expensive and more compact, bubble memory becomes affordable, and as optical memory cards (the size of credit cards) are developed, a Dynabook will be realized. This is a small portable computer with prodigious power and capability first conceived in 1972. Optical memories will mean that complex instructional programs can be used. The Dynabook will enable students to realize another dream—time- and space-flexible learning.

*A Los Angeles software firm is developing a windowing program that will, for about $350, give typical microcomputers windowing capabilities. This is an option worth having as an interim function.

Artificial Intelligence

As impressive as the development of hardware has been, the most striking and challenging advance in computer-based technology will come from what is called artificial intelligence—the ability of computers to deal with complex problems and to learn from experience.

Artificial intelligence implies (Feigenbaum 1983) that the computer can (1) do things that humans consider intelligent (e.g., playing chess, recognizing a face, plotting a path to avoid furniture, participating in a reasonable conversation) and (2) learn from experience and bring its general knowledge of the world to bear on a new problem. In effect, the computer must be able to generate new computer programs in response to natural language commands or a problem identified by the computer itself.

True artificial intelligence will probably emerge sometime between 1995 and 2015. Computers with complex learning and problem-solving abilities—artificial intelligence—will have a revolutionary effect upon the social structure of the world and the psychological development of people.

Before that happens, vocational education will be able to use advances in artificial intelligence to design tutorial programs in which computers take the role of colleague, mentor, and guide to students in a remarkably human way (Collins 1980). Computers will store (1) knowledge of the subject, (2) an evolving model of the student (preferences, weaknesses, present knowledge and skill), and (3) rules for effective instruction. For example, if a student asks about a given agricultural product in Venezuela, the computer might supply the information and then ask how the climate of Brazil might effect the same crop. The aim would be to build continually on what the student already knows, to get the student to apply that knowledge to new situations, and to challenge the student to acquire new knowledge and skill.

Human/Computer Symbiosis

One of the difficulties in separating long-term developments from near-term ones is that there is no sharp dividing line between them. The beginnings of many "blue sky" speculations are present in some rudimentary form today. An example of this is the intriguing symbiosis of computers and humans that is emerging.

In a sense, we already have human-computer symbiosis whenever a human works with a computer to solve a problem that could not be solved without the help of the computer. However, many more dramatic possibilities may be conceptualized. The future applications of robots, for example, are many, varied, and exciting.

Robots are rapidly being introduced into industry. What is less obvious is that robots may be an excellent tool for vocational training (Braun 1983). A robot can do things that would be lethal, or at least unhealthy, for a human (e.g., clean up a radioactive spill at Three Mile Island) and venture where no person can go. Through the use of vidicon eyes, a mass spectrometer nose, transducer touch, and microphone ears, a robot could give us the information for four of the five human senses. This information could be presented in interesting ways so that we become almost a partner of the robot. For example, by wearing transducer-equipped gloves we can feel through our fingers what a robot is grasping. The communication can take place in both directions. We could direct the robot to move and sense what movement takes place.

If the robot had its own built-in computer, an instructional dialogue could take place that would educate both the robot and the human. Each would have abilities lacking in the other.

Together, they would be something more than either is alone—just as a person and a bulldozer are more than either alone. For example, robots could "see" in the infrared, ultraviolet, or even X-ray band of the electromagnetic spectrum where humans cannot, whereas humans can detect visual patterns much better than robots. The robot would have greater strength, but the human would have better complex motor skills. (Two-legged robots can't walk yet—let alone chew gum at the same time.)

Another form of human-computer symbiosis involves implanting computer chips in the human body. This will come about initially for medical conditions that can be helped by a computer-aided prosthesis. For example, people who need artificial limbs are participating in research projects in which a computer chip is connected to the nerve endings where the artificial limb is attached and to the motors that control the artificial limb. These individuals can then move the artificial limb by merely thinking about executing the movement. The thought sends a nerve signal to the computer, and the computer then sends the signal to the motors. Experiments using computer chips to transmit sound signals directly to the nerves that feed into the auditory part of the brain are underway with some positive results.

It seems that once a line of research begins to show some results, progress is inexorable as long as research and development talent is allocated to the problem. Deafness and blindness afflict so many persons that resources will continue to be invested in computer-aided prosthesis. A good example of this is the Kurzweil Optical Reader. The Kurzweil Reader uses a computer program to interpret printed characters so that a voice synthesizer can read aloud to blind people. Since the characters are turned into a digital code, the same technology now serves to enter printed material into computer memory without the effort of typing every character by hand. We can expect this kind of spin-off between computer-related fields to occur repeatedly and to accelerate the development of startling new applications that seem like science fiction.*

A Vision of the Future

The potential relationship of implant technology to vocational education is that perhaps someday in the far-off future the implanted computer chip could act as an expert consultant-tutor that would always be available. Is it realistic to think of an implanted computer chip that could respond to thoughts and feed information directly into the neural system? Some experts expect that this will someday become a reality.

Embedded training, another, somewhat less fantastic vision of the future, involves a computer with a training and job-aids program as an integral part of the work site. Each piece of complex equipment, such as an automobile, a copying machine, a lathe, a sewing machine, a rocket launcher, or a television set would have a computer built into it to assist people in using or repairing the equipment. The computer would be equipped with (1) sensors—so it could monitor a student's activities and the condition of the equipment; (2) the student's preprogrammed profile—so it could make appropriate instructional decisions; and (3) extensive knowledge related to the work being done. For example, in turning on a machine, there is often a series of steps that must be taken in a certain order to prevent damage to the machine. A computer can be wired into the system to detect those steps and to teach the student to carry them out in the correct order. Even after the student has completed training, the computer can still monitor the process and ask the student, "Are you sure you want to start the lathe now? The electric motor temperature is at the

*Many ideas that are becoming reality—including those above—first appeared in science fiction literature. We owe many science fiction authors a debt for keeping our minds open to the future.

upper limit." Or, "Did you fasten down the chuck after you changed the tool? The sensors indicate incorrect pressure."

Students could also request training from embedded computers. For example, if students are given the task using a new material, they could ask for a lesson on how the tool angle, the tool material, the lathe speed of rotation, and the feed speed should be adjusted for different results.

The embedded computer could also serve as a reference tool providing job aids for a skilled worker who has forgotten some particular piece of information. For example, an employee may need to know the company procedure for shutting down a machine for a major change that occurs only once a year. Once reminded, the worker may have enough knowledge and background to apply the steps without further training. Maintenance is a good example of the application of this concept, and many firms are developing such aids.

The U.S. Defense Department's Defense Advanced Research Projects Agency (DARPA) supported the development of a novel, audiovisual helmet to aid in military equipment repairs. Often such repairs must be made in close quarters with reference to detailed illustrations and technical manuals. To speed up the work, soldiers wear a helmet that enables them to give spoken commands to a computer. The computer can, in turn, provide spoken messages to the soldiers and also show them relevant illustrations on a visor that flips down in front of their eyes. This helmet presently is moving from the prototype stage to the pilot-testing stage.

A device of this kind would be invaluable in such common civilian jobs as automobile maintenance which are becoming so complex that repair workers can hardly keep up-to-date. Of course, the most complex equipment needing this kind of embedded aid is the computer itself. Manufacturers are beginning to embed training related to each computer in the computer.

The above discussion assumes that for the foreseeable future (until 2025 to 2050) people will be able to do many important tasks that a computer cannot. Thus a continuing need will exist to train people in those skills. As noted above, a pattern of partnership between human and machine intelligence is gradually building with augmented capacity for people as a result.

Embedded Training: A Scenario

A worker with no previous training on a lathe is told to learn to operate a particular lathe. (This example assumes that not all lathe operations will be carried out by robots.) A powerful computer is wired into all operations of the lathe and has sensors that make it "aware" of almost everything that is happening to the lathe and in the near vicinity of the lathe. The computer controls a videodisc, has network access to other computers and large information libraries, has a large (forty thousand volume) library of its own, can provide hard copy, and is equipped for voice output, speech recognition, and the production of sophisticated, computer-generated graphics.

Since embedded training is commonplace, the worker does not hesitate to approach the machine. Turning on the first switch involves the trainee in dialogue with a machine that will guide and teach, anticipate most errors, and be an extremely patient teacher. An experienced operator would use a special code to bypass unnecessary instruction. When the code is not used, automatically the embedded computer program says (using synthesized speech), "Are you an inexperienced lathe operator?" The trainee answers, "Yes." Speech recognition circuits can easily interpret this spoken answer. The way the trainee speaks is analyzed by the computer so as to begin recognizing the specific aspects of the individual's voice needed for comprehension of more complex statements.

The computer then engages the trainee in a program that uses a computer-controlled videodisc to teach the operation of the computer. The large, flat computer screen is touch sensitive. Voice recognition and voice synthesis help the trainee continue learning while his or her hands are occupied, but occasionally the program required touch responses such as touching a picture of a part of the lathe that controls a certain function.

A videodisc serves several functions. First, it displays the way a skilled lathe operator performs several operations. The visual model with voice commentary provides a general idea of the direction of learning. This makes the learning process more efficient. The "model of skilled performance" provides a kind of latent template. As the worker develops new skills in operating the lathe, he or she can place them in the context, forming a mental picture of the model. The model helps the trainee decide when things are done correctly or incorrectly by serving as a reference standard.

Second, the videodisc can visually display a wide range of events that would otherwise be unavailable for instruction. X-ray or infrared motion pictures of a developing fracture, microscopic pictures of a poorly sharpened tool, or demonstrations of the use of different attachments, for example, can be magnified and viewed from different angles in stop-action or slow-motion. Third the videodisc permits the trainee to engage in simulations that are low-cost equivalents of the desired skill. The computer provides a simulation of the three dimensional feel of an actual lathe (by using servo-mechanisms).

When the trainee begins to operate the lathe, the computer continually monitors his or her performance. If the trainee attempts to perform an operation that would damage the workpiece or the machine, the embedded computer training program says, "Are you sure you want to do that?" The trainee then says, "Why not?" The computer answers, "Let's carry out that operation in a simulation mode to show you what would happen."

If the machine breaks down because of wear or an internal defect, the computer either uses this event to teach the trainee to diagnose the fault or simply identifies the fault and teaches the trainee how to repair it. Upon request, the computer uses the breakdown to illustrate some principle that has been taught earlier. The videodisc program takes the trainee as deeply into metallurgy and design theory as he or she is willing to go. A truly "friendly" program that continually alternates between theory and practice, embedded training is one of the most interesting and motivating learning environments.

An Agenda for the Future

The following are recommendations to enable vocational education to capitalize on the new computer-based information technologies:

- Organizations must devote more effort to designing organizational structures to help workers be more productive and to make use of the latest training technology.

An organizational structure should help people to be productive with the technologies, the tools, at their disposal. A key element in the future will be the extent to which organizations can continually improve the knowledge and skill of their workers. This includes general strategies for dealing with new problems and situations, basic knowledge in science and math, and specific training in new equipment and techniques. As technology becomes more complex, vocational

education, government, and business policymakers and planners should invest substantial resources in designing ways for institutions and firms to reorganize to meet the training imperatives of the future.

- Education and training systems must apply cognitive science to education, training, and retraining.

The United States has often been accused of having an anti-intellectual bias (Feigenbaum 1983). Ideas that, in the past, were looked upon as too theoretical and impractical are now a vital national resource. However, ideas such as those that illuminate how people learn are only useful if they are valued and widely accepted. If the results of cognitive science research are not respected, supported, and sought, no amount of money or technology will be productive.

- We should develop a national commitment to excellence in training.

The needed planning for reorganization, for investments in revitalizing vocational education programs, for support of research and development in vocational education, and for other needed efforts will not occur without a broad commitment to the development of knowledge and skill in members of the work force.

- Industry must organize and fund industrywide course-development projects.

A wide spectrum of specific course-development projects should be funded. These projects should be located in education research and development centers, educational institutions, individual firms, industrywide course-development centers, and private publishing houses. The government should find ways to support developmental efforts in the private sector without eroding the profit incentive. Development of courses in basic science, math, and technology—the raw material for functioning in the knowledge age—should be primarily supported by public funds with input from employers. At the least these questions should be widely considered and debated until some broad-scale initiatives can be agreed upon and started.

- Support is needed for research and development in the training applications of the new information technologies.

The use of the new information technologies in training requires extensive front-end investment in research and development. At the present time, little systematic effort goes into developing the institutions, the equipment, and the people needed for effective high-quality research. As a result, efforts well begun often die when individual, superhuman effort is gradually worn down.

- Support should be developed for research into the learning process—particularly learning in the vocational field. Especially important is research into new representations of knowledge.

It seems clear that procedural skills require a different kind of learning than most academic courses require. We do not sufficiently understand how to teach the wide range of skills and attitudes needed for effective workers who can cooperate with employers but who are also independent-minded citizens. The skills include the ability to consider the state of the world and where it is going, high level strategic skills for organizing one's own and others' time to work toward new goals, and the application of specific procedures to a well-defined task.

We should seek to invent new representations of important areas of vocational knowledge rather than just try to teach the old formulations more effectively. Representations can often make

a great difference in the ease of comprehension and learning. If mankind had discovered the very best way to teach arithmetic with roman numerals and were content with that, the world would be decades or centuries behind where it is today. The simple shift from the roman to arabic numbering system tremendously simplified arithmetic computation—for everyone.

Another example—one with great industrial significance—was the use of imaginary numbers to represent electrical phenomena. With imaginary numbers, great simplifications of notation and mathematical procedure are possible. As cognitive science gathers momentum, we will become more aware of the importance of good representations of ideas and procedures. This issue deserves considerable thought on the part of investigators in vocational education.

- The education system should develop professional undergraduate and postgraduate degree programs for people who will create instructional materials for the new computer-based educational technology.

The body of knowledge that could be profitably learned and applied is great—spanning most of the social and behavioral sciences as well as education and the techniques of production (Fisher 1983). Yet there are few college programs in existence designed to prepare people who can effectively create new materials through the orchestration of the new information technologies at our disposal.

A GLOSSARY OF COMPUTER TERMINOLOGY

Analog. An analog device represents and measures numerical quantities with physical variables such as displacement, currents, voltages, and so forth. Thus, electrical resistance in an analog representation of a system can represent heat losses in the system. An LP record is an analog representation of sound. A clock with hour, minute, and second hands is an analog representation of time.

Artificial Intelligence (AI). AI is the ability of a machine (computer) to engage in what we call intelligent behavior and to learn from experience. Expert medical diagnostic systems, systems that search data for evidence of mineral deposits, game-playing programs, programs that understand natural language, and problem-solving programs are examples of AI fields.

Author. In the context of this paper, an author is one who creates instructional lessons for computer-based instructional systems that may use any and all audiovisual media.

Authoring Program or System. An authoring system is a computer program that enables someone who is not a computer programmer to create computer-based lessons. The program takes the instructions of the author and generates the detailed computer code needed.

BASIC. BASIC is a computer language developed at Dartmouth College. It was designed to be easy for beginners to learn. Many personal computers are designed to use BASIC.

Bit. Bit stands for *binary digit*. It is the smallest unit of data. Any message can be represented by a series of ones or zeros. Each one or zero is a *bit*, the smallest bit of message.

Bubble Memory. Bubble memory is a storage technology in which data are represented by tiny cylindrical magnetic domains in a thin film of magnetic material. The magnetic bubbles are generated and detected electronically. As a result, bubble memory requires no moving parts. Since the bubbles are permanent magnets, the memory does not require electric current to be operating in order to keep it from being lost.

Byte. Byte is eight bits (see bit). A byte is significant because in most computer systems it takes 8 bits to represent all the alphabetic, numerical, and other characters used. Most memory figures (e.g., 64K) are given in bytes, 64K of memory can hold 64,000 characters.

Cathode Ray Tube (CRT). A television screen is a cathode ray tube. We can see a picture because electrons (cathode rays) are accelerated by an electrical voltage (about 10,000 volts). When the electrons hit the screen, the energy of the electrons is converted into light.

Computer Network. A computer network is a communication system that permits computers to send messages to other computers. With suitable devices to manipulate the electrical signals, the telephone system can be used to connect a computer network.

Course-Management Program. A course-management program is a computer program that keeps track of students' progress and test scores, and the length of time they spend in a unit. The program also may indicate what they should do next or what kind of approach should be taken to capitalize on their strengths and minimize their weaknesses.

Cursor. A cursor is the bright spot of light (usually rectangular) on a computer screen that indicates where the next character will appear.

DARPA. DARPA refers to the Defense Advanced Research Projects Administration, a Defense Department agency whose mission is to support the development of advanced technology for the U.S. armed forces.

Degradation of Performance. This term refers to a decrease in the quality of performance of a computer when it is overloaded (too many people trying to use the computer at the same time). This usually results in the computer taking longer to respond to a command.

Disk (or diskette). A floppy disk is a thin, flexible, circular plate coated with magnetic material. A magnetic head similar to the heads of a tape recorder magnetizes or demagnetizes small areas of the magnetic material. The magnetized areas store information. The information can be read by the head and the head can write on the disk. Disks come in various sizes. A disk is usually eight inches in diameter and a diskette is usually five inches in diameter. Mini- and microdiskettes are also available. A hard disk has magnetic material deposited on a rigid plate. A hard disk can usually contain more information and operate more rapidly than a floppy disk.

Dumb Terminal. This is a computer terminal that has no computational power of its own. A dumb terminal can only send and receive information from a computer.

Dynabook. A small portable computer of immense power and large memory, the Dynabook was conceived in 1972. At the time, it seemed impractical, but it is becoming a reality.

Electroluminescence. This results from material that gives off light when an electrical field is applied.

Electronic Bulletin Board. An electronic bulletin board consists of computer files that can be added to or read by anyone who has access to a computer network. For example, someone may have a file called "High-Fidelity Equipment." Then any member of the network can ask a question or put in a piece of information about "hi-fi." For example, someone may leave a message in the file asking, "Does anyone know if the Majorana 137 is a good amplifier?"

Electronic Mail. This involves sending messages from one computer to another. Commercial electronic mail services are available.

Floppy Disk (see Disk). A floppy disk is a flexible disk with a magnetic coating for storage of digital information.

Font. Font refers to a style of type. Each different style of type has a name (usually derived from the printing trade).

FORTRAN. FORTRAN is a computer language widely used to write engineering programs.

Graphics. Figures, line drawings, and computer-generated art that appear on a computer screen are known as graphics. Many of the special effects in movies are the result of computer graphics programs.

High-level Language. A high-level computer language allows the person working with the computer to use terms familiar to him or her in writing commands for a computer.

High Resolution. A high-resolution picture screen shows fine detail clearly. American television is broadcast in low resolution compared to European television.

Intelligent Terminal or Smart Terminal. An intelligent terminal possesses computational power and can perform many operations.

Interactive Device. A computer-controlled videodisc is an example of an interactive device. The student interacts with the material on the disc by typing commands into a computer. For example, a videodisc frame asks a question. If it is answered correctly, a different picture is shown than if it is answered incorrectly. Of course, the interaction can be much more complex.

Laser. Laser is an acronym that stands for light amplification by stimulated emission of radiation. A laser beam has an extremely narrow range of wavelength.

Liquid Crystal Display (LCD). An LCD is a display panel of the kind seen in most digital watches. An electric field changes the response of liquid crystals to light. A liquid crystal display does not give off light of its own.

Mainframe. Mainframe refers to a large computer with many components that is capable of a large number of computations.

Mass Spectrometer. A mass spectrometer is a device for analyzing the molecules of a material. In one kind of mass spectrometer, an electron beam ionizes the material to be analyzed. An electric field accelerates the ions toward a magnetic field. The magnetic field bends the path of the ions. More massive ions are more difficult to bend and so different masses take different paths. The different masses are detected electronically.

Megabyte. Mega means million, so a megabyte of memory contains a million bytes of memory. It can store a million characters.

Menu. Menu refers to a list of choices. Usually the menu is displayed on the screen with a number or a letter beside each choice. If one types a letter or number, one goes to the point in the program represented by the letter or number. For example, if a book were stored in the computer, the table of contents could be used as a menu to access various parts of the book.

Menu Driven. This term means that the operator commands the computer by making successive choices from menus. For example, in a word processor program, the operator can call up a particular letter from a menu, decide to change the format by a selection from a menu, and command the computer to store the document by a choice from a menu. Menus minimize the need for the operator to memorize commands in order to use a computer.

Nonvolatile Memory. Nonvolatile memory refers to stored information that is not lost when the computer is turned off or when the power fails.

Optical Character Reader (OCR). An OCR is a device that "reads" printed characters and converts the information into computer code.

Optical Memory. Optical memory refers to an information storage device that involves a laser beam (see Laser). Tiny pits (indentations) in a solid material carry the information. The laser beam is reflected by the pits and the stored information is detected electronically.

Optical Memory Card. This is a small plastic card that contains millions of pits carrying information. A single card the size of a credit card can carry millions of characters.

Optical Videodisc. An optical videodisc is a videodisc that is read by a laser beam. This is in contrast with videodisc technology that reads the information with a needle.

PASCAL. PASCAL is a modern computer language that many experts feel is an improvement over BASIC, a widely used computer language (see BASIC).

PLATO. PLATO is a computer-based education system developed at the University of Illinois.

Peripheral Device. A *peripheral* is a device that connects to a computer to carry out some function (e.g., printer, videodisc player, joy stick).

Random Access Memory (RAM). RAM is an array of solid-state units on a microchip. Each unit has a numerical address and a place to store a message. A message can be retrieved from the unit or placed on the unit by specifying the address. The operator has random access to any message by simply specifying the address.

Read Only Memory (ROM). Messages in read only memories are placed on a solid state device at the factory. The user cannot change the messages. The messages in ROM can only be read (transferred from the ROM to some other place such as the RAM).

Servomechanism. A computerized system that allows smooth motion and controlled speeds in mechanical devices such as robots.

Software. A computer program is referred to as software. Sometimes a videodisc or game cartridge is also called software.

Still-Frame Audio. A spoken (sound) message that is heard while a single (still) frame is shown on the TV screen is known as still-frame audio. This is very similar to a slide-tape program.

Still-Frame Capability. The ability to keep a single frame of a videodisc on the TV screen is referred to as still-frame capability. It is analogous to stopping a movie film and keeping a single picture projected on the screen. In the case of the videodisc, this is done electronically.

Transducer. A transducer is a device that changes pressure or changes in pressure into an electrical signal. A phonograph needle is a transducer.

TUTOR. The special language that was developed for authors using the PLATO system (see PLATO) is known as TUTOR.

"User Friendly". This term describes a system or a device that can be used successfully by a novice.

Videodisc. A videodisc is a device the size of an LP record (twelve inches in diameter) that contains information sufficient for one-half to one hour of television or 50,000 individual pictures. The information is represented by millions and millions of tiny pits in the surface of the disc. The pits are detected by reflecting a laser beam (see Laser) from the pits. The reflected beam is detected electronically. The pattern of electrical signals is transformed by the electronic system into the form needed to generate a television signal.

Vidicon. A vidicon is a television camera.

Voice Synthesis Program. This is a program that synthesizes human speech from the stored information that creates tiny bits of sound (phonemes). Voice synthesis allows a computer program to command the computer to generate any spoken message.

Volatile Memory. Volatile memory refers to information storage technologies in which the information is lost when electrical power is lost. Most RAM (see RAM) is volatile memory.

WISE. WISE is an authoring program designed to enable nonprogrammers to create computer-based lessons. WISE enables the author to create line drawings and text of almost any size and to shift text and graphics (see Graphics) on the screen. WISE also enables the author to generate several different kinds of questions for students and to interpret their answers. Typically, using WISE, one can create a lesson in one-tenth of the time it would take if a programmer had to create the same lesson.

Workstation. Workstation refers to the equipment students use in computer-based education. A student workstation usually consists of a computer screen and a keyboard. However, it may include many other devices (e.g., joy stick, videodisc player, screen, printer). One or a few students usually sit at a workstation in order to work on a lesson.

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